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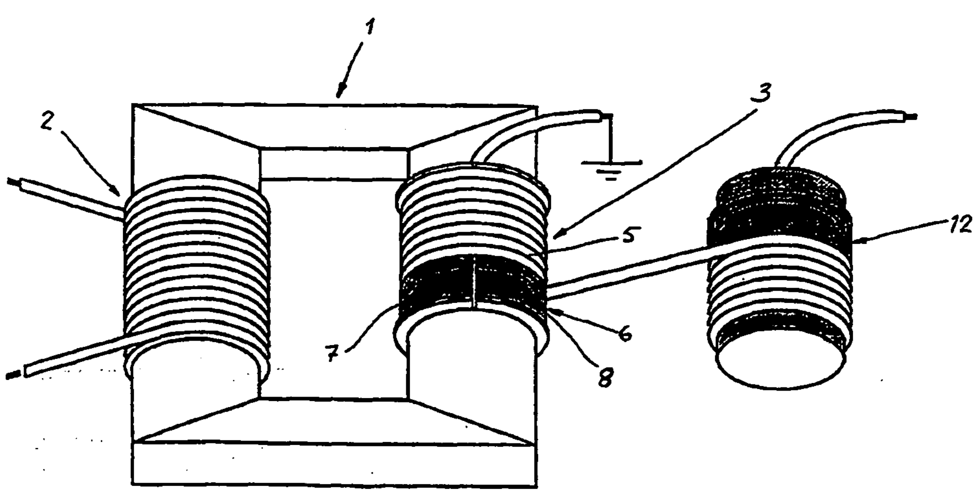

(57) Abstract

The invention relates to a method for regulating an induced voltage in transformer, alternatively reactive power of a reactor, wherein a winding (5; 26) is achieved with an insulating electric conductor including at least one current carrying conductor, a first layer having semiconducting properties arranged to surround the conductor, a solid insulation layer arranged to surround said first layer, and a second layer having semiconducting properties arranged to surround the insulating layer, wherein a regulating winding (3, 22) is arranged around a magnetic flux carrier (1), and wherein the length of said regulating winding around the magnetic flux carrier is varied. The invention also relates to an arrangement for the realization of the method and a transformer/reactor including such an arrangement.

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A method and an arrangement for regulating a transformer/reactor, and a transformer/reactor

The present invention relates to a method and an arrangement for regulating an induced voltage in a transformer, alternatively regulating the reactive power of a reactor.

The present invention relates furthermore to a transformer/reactor as defined in the preamble of Claim 36.

The present invention relates both to transformers and reactors having a core, as described below, as well as air-cored transformers and reactors.

For all transmission and distribution of electric energy, transformers are used and their task is to allow exchange of electric energy between two or more electric systems. Transformers are available in all power ranges from a few VA up to the 1000 MVA region. The designation power transformers normally relates to transformers with a rated output from a few hundred kVA up to more than 1000 MVA and with a rated voltage ranging from 3 - 4 kV and up to very high transmission voltages.

A conventional power transformer includes a transformer core, referred to below as the core, made of laminated, preferably oriented sheet metal, usually of silicon steel. The core consists of a number of core legs connected by a yoke. A number of windings are provided around the core legs in the form of primary, secondary and regulating winding. In power transformers these windings are practically always arranged in concentric configuration and distributed along the core legs.

Conventional power transformers at the lower end of the aforementioned power ranges, are at times manufactured having air-cooling for the removal of inevitable losses in the form of heat. Most conventional power transformers are however oil-cooled and then as a rule by means of so-called forced oil-cooling. This applies especially to high-power transformers. Oil-cooled transformers present a number of known disadvantages. They are among other things large,

cumbersome and heavy contributing especially to great transport problems. Extensive requirements need also to be met with regard to security and peripheral equipment, of which the requirement for an outer tank is especially noteworthy, in which the transformer is to be contained in the event of oil-cooling.

It has however largely been shown possible to replace oil-cooled power transformers with dry transformers, i.e. oil-free transformers, of a new type. This new type of transformer is provided with a winding designed with high voltage insulated electric conductors, having solid insulation, of a design similar to cables used for transmitting electric power (for example so-called XLPE cables). Consequently, dry transformers of this new type may be used at considerably higher powers than what was possible with dry transformers according to prior art.

With regard to reactors, they include a core which is usually provided with only one winding. Moreover, that which is stated in the aforementioned about transformers is generally also applicable to reactors. It is especially noteworthy that large reactors are also oil-cooled.

For different reasons it is often necessary to be able to regulate or adjust the voltage of a power transformer. This may for example apply to maintaining the secondary voltage constant with a varying primary voltage; variation of secondary voltage; providing a reduced voltage in order to start a rotating machine; providing a neutral point for earthing or for dealing with out of balance current in different circuits etc. For this reason transformers are provided with an adjustable winding, referred to below as a regulating winding, which may adjust the transformer ratio.

Regarding transformers for low voltages it is previously known from FR 805 544 and GB 1 341 050 to vary the effective length of the winding by means of a regulating winding drum onto which the winding is wound or unwound. However, this application is strictly limited to lower voltages due to the completely different type of winding used in

high-power transformers, where the winding is rigid, as well as insulation problems associated with such a winding.

Known technique for conventional power transformers in the higher power ranges, i. e. oil-cooled transformers, is set forth in, for example, "The J&P Transformer Book" (A. C. Franklin et al, 11th Edition 1983), describing how regulation may take place in different ways. The two most common ways are firstly the use of so-called off-load tap changers in which tapping may take place between different voltage outlets inside the transformer tank, which can only take place when the transformer is off-circuit, and secondly the use of so-called diverter switches in which tapping takes place between different voltage outlets extended to the outside of the transformer tank and which can therefore take place on-load.

During this tapping, parts of said regulating winding are thus connected to the concerned winding side so that the desired voltage regulation is obtained. This must take place stepwise where a typical value of the steppings between taps is 10 winding turns. This arrangement presents the disadvantage that despite a relatively large amount of taps, which are necessary to give a reasonable amount of regulation possibilities, the regulation possibilities are still limited and far from a stepless regulation.

Correspondingly, reactors may be provided with a regulating winding by means of which the reactive power of the reactor may be regulated and which presents the corresponding problem.

The object of the present invention is to provide a method and an arrangement to solve the aforementioned problems and which allows for improved regulation possibilities for transformers, alternatively reactors, especially of the dry type, in the high power range. Another object is to obtain such an improved transformer/reactor.

These objects are achieved by means of a method, as defined in Claim 1, as well as by an arrangement as defined

in Claim 10. The object is further achieved by means of a transformer/reactor as defined in Claim 36.

The present invention relates thus to a method for regulating induced voltage in a transformer, alternatively for regulating reactive power in a reactor, wherein a winding is achieved with an insulating electric conductor including at least one current carrying conductor, a first layer having semiconducting properties arranged to surround the conductor, a solid insulation layer arranged to surround said first layer, and a second layer having semiconducting properties arranged to surround the insulating layer, wherein a regulating winding is arranged around a magnetic flux carrier, and wherein the length of said regulating winding around the magnetic flux carrier is varied.

The magnetic flux carrier may be a transformer core or a reactor core, as described above. However, both the method and the arrangement according to the present invention are applicable also to air-cored transformers and reactors, as also mentioned above.

According to the invention a corresponding arrangement is defined, wherein said transformer/reactor includes at least one magnetic flux carrier and a winding achieved with an insulating electric conductor including at least one current carrying conductor, a first layer having semiconducting properties arranged to surround the conductor, a solid insulation layer arranged to surround said first layer, and a second layer having semiconducting properties arranged to surround the insulating layer, wherein said arrangement further includes a regulating winding and a regulating means, by means of which the length of said regulating winding around the magnetic flux carrier is varied.

The defined method and arrangement have the advantage that the length of the regulating winding may be regulated continuously in a very simple manner, also in high voltage transformers and reactors. However, an important precondition to make this possible, is that the winding of the transformer/reactor is designed with the aforementioned

type of high-voltage insulated electrical conductor. Through the use of such a conductor, or cable, the advantage is achieved that the insulation problem is solved, which would occur when a conventional winding is wound onto or unwound from a regulating drum. Thereby, it is made possible to use, for instance, drum regulation of the winding also for high voltages, i.e. in distribution and power transformers.

Accordingly, the windings, in the arrangement according to the invention, are preferably of a type corresponding to cables having solid, extruded insulation, of a type now used for power distribution, such as XLPE-cables or cables with EPR-insulation. Such a cable comprises an inner conductor composed of one or more strand parts, a first, inner semiconducting layer surrounding the conductor, a solid insulating layer surrounding this and a second, outer semiconducting layer surrounding the insulating layer. Such cables are flexible, which is an important property in this context since the technology for the arrangement according to the invention is based primarily on winding systems in which the winding is formed from cable which is bent during assembly. The flexibility of an XLPE-cable normally corresponds to a radius of curvature of approximately 20 cm for a cable with a diameter of 30 mm, and a radius of curvature of approximately 65 cm for a cable with a diameter of 80 mm. In the present application the term "flexible" is used to indicate that the winding is flexible down to a radius of curvature in the order of four times the cable diameter, preferably eight to twelve times the cable diameter.

The winding should be constructed to retain its properties even when it is bent and when it is subjected to thermal or mechanical stress during operation. It is vital that the layers retain their adhesion to each other in this context. The material properties of the layers are decisive here, particularly their elasticity and relative coefficients of thermal expansion. In an XLPE-cable, for instance, the insulating layer consists of cross-linked, low-density polyethylene, and the semiconducting layers consist of poly-

ethylene with soot and metal particles mixed in. Changes in volume as a result of temperature fluctuations are completely absorbed as changes in radius in the cable and, thanks to the comparatively slight difference between the coefficients of thermal expansion in the layers in relation to the elasticity of these materials, the radial expansion can take place without the adhesion between the layers being lost.

The material combinations stated above should be considered only as examples. Other combinations fulfilling the conditions specified and also the condition of being semiconducting, i.e. having resistivity within the range of 10^{-1}-10^{6} ohm-cm, e.g. 1-500 ohm-cm, or 10-200 ohm-cm, naturally also fall within the scope of the invention.

The insulating layer may consist, for example, of a solid thermoplastic material such as low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polybutylene (PB), polymethyl pentene ("TPX"), cross-linked materials such as cross-linked polyethylene (XLPE), or rubber such as ethylene propylene rubber (EPR) or silicon rubber.

The inner and outer (first and second) semiconducting layers may be of the same basic material but with particles of conducting material such as soot or metal powder mixed in.

The mechanical properties of these materials, particularly their coefficients of thermal expansion, are affected relatively little by whether soot or metal powder is mixed in or not - at least in the proportions required to achieve the conductivity necessary according to the invention. The insulating layer and the semiconducting layers thus have substantially the same coefficients of thermal expansion.

Ethylene-vinyl-acetate copolymers/nitrile rubber (EVA/NBR), butyl graft polyethylene, ethylene-butyl-acrylate copolymers (EBA) and ethylene-ethyl-acrylate copolymers

(EEA) may also constitute suitable polymers for the semiconducting layers.

Even when different types of material are used as base in the various layers, it is desirable for their coefficients of thermal expansion to be substantially the same. This is the case with the combination of the materials listed above.

The materials listed above have relatively good elasticity, with an E-modulus of E<500 MPa, preferably <200 MPa. The elasticity is sufficient for any minor differences between the coefficients of thermal expansion for the materials in the layers to be absorbed in the radial direction of the elasticity so that no cracks appear, or any other damage, and so that the layers are not released from each other. The material in the layers is elastic, and the adhesion between the layers is at least of the same magnitude as in the weakest of the materials.

The conductivity of the two semiconducting layers is sufficient to substantially equalize the potential along each layer. The conductivity of the outer semiconducting layer is sufficiently high to enclose the electrical field within the cable, but sufficiently low not to give rise to significant losses due to currents induced in the longitudinal direction of the layer.

Thus, each of the two semiconducting layers essentially constitutes one equipotential surface, and these layers will substantially enclose the electrical field between them.

There is, of course, nothing to prevent one or more additional semiconducting layers being arranged in the insulating layer.

An example of an insulated conductor or cable suitable to be used in the present invention is described in more detail in WO 97/45919 and WO 97/45847. Additional descriptions of the insulated conductor or cable concerned can be found in WO 97/45918, WO 97/45930 and WO 97/45931.

According to the present invention, the method may further be characterized in that said regulating winding is arranged on a regulating means, said regulating means being rotatable around said magnetic flux carrier. As another feature, a variable part of the regulating winding is transferred to or from at least one storage means.

A further preferred feature is that the method is characterized in that the transformer/reactor includes a main winding which may be connected to the regulating winding. The method is furthermore characterized in that, starting from a zero position in which there are no turns on the regulating winding drum, the induced voltage/reactive power of a transformer/reactor respectively, is increased in that the winding is wound onto the regulating winding means in the same direction as the direction of the main winding, and that the induced voltage/reactive power of a transformer/reactor respectively, is decreased in that the winding is wound onto the regulating winding means in the direction opposite to the direction of the main winding, whereby the maximum variation of the number of winding turns is +-N, where N is the number of winding turns which are available on the regulating winding means. The advantage achieved hereby is that the winding may either be varied stepless or by an optional number of turns, unlike prior art in which only predetermined combinations of the number of turns was possible.

According to a particular feature the regulating means includes a rotatable regulating winding drum.

Winding up the regulating winding in one direction corresponds naturally to an unwinding of the regulating winding in the opposite direction. Should the whole regulating winding be rolled-on in one direction, which is assumed to be the same as the winding direction of the main winding, obtaining therefore a maximum induced voltage/reactive power, a reduction of the voltage/power naturally takes place by unwinding the regulating winding firstly before starting to wind it up in the opposite direction.

The arrangement, according to the present invention, may further be characterized in that the regulating winding is arranged on said regulating means and that the regulating means is rotatable around said magnetic flux carrier. As a further feature, it includes means for the transfer of a variable part of the regulating winding to or from at least one storage means. To continue, it includes the preferred features that the regulating means includes a rotatable regulating winding drum, and that the storage means includes a rotatable storage drum. The winding up and the unwinding preferably takes place by arranging the regulating winding onto a rotatable means, such as said drum, but other solutions are also possible. Also other solutions regarding the storage means are conceivable, such as several drums, a reel or coil, etc. or nothing at all.

According to another preferred feature the regulating winding may be arranged onto a magnetic flux carrier leg appertaining to one phase of a polyphase system and the main winding may be arranged onto a magnetic flux carrier leg belonging to another phase of the polyphase system. This has the advantage of enabling a phase shift.

According to yet another preferred feature the storage means may include a second winding arranged around a magnetic flux carrier belonging to another phase of the polyphase system than the regulating winding. With this arrangement both voltage control, by means of the regulating winding, and phase shift, by means of the second winding, can be achieved.

The arrangement is further characterized in that the transformer/reactor includes a main winding and that the regulating winding is provided with means for electrical connection to the main winding. The arrangement is also characterized in a particularly preferred way in that, starting from a zero position, in which there are no turns on the regulating winding drum, the induced voltage/reactive power of a transformer/reactor respectively, is increased in that the said means for transferring the winding are adapted to

winding up the winding onto the regulating drum in the same direction as the direction of the main winding, and that the induced voltage/reactive power of a transformer/reactor respectively, is reduced in that said transferring means are adapted to winding up the winding onto the regulating winding drum in the direction opposite to the direction of the main winding, whereby the maximum variation of the number of winding turns is +-N, where N is the number of winding turns which is available on the regulating winding drum.

The arrangement displays furthermore the preferred feature that the transferring means includes a drive means for the rotation of a regulating drum and a drive means for the rotation of a storage drum. These drive means are preferably in the form of at least one motor and a device for belt driving the respective drum. It is thus possible for a common motor to drive the regulating winding drum as well as the storage drum. Each drum having its own motor is another possibility. The transformer may also be of a polyphase type. In a transformer of a three-phase type, for example, thereby having three regulating windings, which may each be independent of the other, it is conceivable that each one of the regulating windings is driven by its own motor so that in total there are three, alternatively six motors, or that all phases are regulated in the same way amounting then to one or two motors depending on whether the respective storage drum is also driven by this motor. Alternatives other than belt driving are naturally feasible.

According to another feature, the regulating winding drum and the storage drum are respectively rotatable in two directions.

Said means for electrical connection to the main winding is, according to one feature, characterized in that it may include a diverter switch. The winding may be varied by one winding turn at a time with the aid of this diverter switch. This has the advantage of producing a significantly higher resolution and possibility of more precise regulation than in the previously known technique.

The core may alternatively be interrupted by an insulating means, whereby earthing, alternatively connection to the main winding, takes place by means of a, from the insulating means, outgoing conductor. The insulating means is preferably designed as a rotatable disk of an insulating material, or a corresponding device. A stepless variation of the length of the regulating winding, which is advantageous, is possible with the aid of the rotatable disk.

As the regulating winding drum is preferably arranged around the core it is preferable to construct it out of at least two drum parts which are joined together in the radial direction in order to form the drum.

According to a particularly preferred feature the insulating electric conductor of said winding has a second layer which is connected to a predetermined potential, preferably earth potential. As mentioned, this has the advantage that the electrical field generated by the current carrying conductor is enclosed within the solid insulation layer. Since this has the result that no electrical field exists outside the winding, the further advantage is obtained that it generally will be possible to apply technique that is previously only known from the low-voltage range and the electronics field.

In accordance with the inventive arrangement, the high voltage electric conductor may be designed to advantage in several ways. It has preferably among other things a diameter lying in the interval of 20 - 250 mm and a conductor area lying in the interval of 80 - 3000 mm^2. The first layer is furthermore essentially at the same potential as the current carrying conductor. The second layer is preferably arranged such that it forms a substantially equipotential surface surrounding the current carrying conductor/conductors. According to other designs at least two adjacent layers have essentially the same thermal coefficients of expansion, the current carrying conductor may include a plurality of strands whereby only a few strands are non-insulated from one another, and finally each one of the

three layers may be securely connected to the adjacent layer along essentially the whole connecting surface.

Another characteristic defined is that at least one of, and possibly both, the regulating winding drum or the storage drum is provided with means for connection of the said second layer of the winding, having semiconducting properties, to a predetermined potential, preferably earth potential. These means may be designed in several ways.

The regulating winding drum is also preferably provided with a means by which to earth the conductors in the winding. This means is preferably in the form of a sliding contact, for example in two halves.

The present invention will now be described in detail, by way of example, with particular reference to the accompanying drawings showing different embodiments and parts of the invention in which:

Figure 1 is a diagram showing the principle of an arrangement according to the invention;

Figure 2 is a diagram showing the principle of an embodiment of the arrangement according to the invention, where the number of turns of the regulating winding are varied by one turn at a time by means of a diverter switch;

Figure 3 is a diagram showing the principle of another embodiment of the invention where the winding may be varied with stepless control;

Figure 4 is a diagram showing the principle of a variant of earthing of the winding;

Figure 5 is a diagram showing the principle of another variant of earthing of the winding;

Figure 6 is a perspective view of a contact suitable for earthing;

Figure 7 shows an cross sectional view of the contact in Figure 6;

Figure 8 illustrates a detail of the contact in Figure 6; and

Figure 9 shows a cross sectional view of an insulated conductor suitable to be used in the present invention.

Figure 1 shows a transformer core 1 consisting of a yoke and two legs, in which a main winding 2 is applied around the one leg and a regulating winding 3 is arranged around the other leg. The main winding may either be formed of a primary winding or a secondary winding. The regulating winding is thus used to vary the ratio of the transformer. The regulating winding 3 is arranged in the form of winding turns 5 wound onto a rotatable drum 6. As can be seen, the drum 6 is divided into two drum halves 7, 8. Other ways of dividing the drum are also conceivable so as to facilitate the installation around the legs of the core. The drum is provided with at least one flange for belt driving by means of a motor (not shown). The regulating winding functions thus as a variable coil. The number of winding turns on the regulating winding drum 6 is made to vary with the aid of a rotatable winding storage drum 12 for the winding 5. The storage drum 12 is likewise preferably belt driven by a motor.

In the following Figures, the same or corresponding parts as referred to in Figure 1, are designated by the same numerals. The symbols A and B in Figures 2, 4 and 5 generally show points of connection for the windings, for example to the main winding or earth.

The embodiment shown in Figure 2 refers to a regulating winding where the length of the winding is varied stepwise by one winding turn at a time. This takes place by means of a diverter switch 15 which is known as such (alternatively termed load coupler).

In Figure 3 another embodiment is shown where the winding on the regulating winding drum may be varied by stepless control. A core 18 is shown here which is divided into two parts 18a, 18b by means of a disk 20 of insulating material. The disk is rotatable and is connected, at its centre, to an outgoing conductor 21, 21a, which passes into and through the core part 18b, and is also connected to a radial conductor 22a in the disk and which conductor is connected to the regulating winding 22. The conductors 21,

21a are thus connected to the winding 22 via the conductor 22a. The winding 22 on the regulating drum 23 is connected to a main winding, an outgoing conductor or to earth potential, via the conductors 22a, 21 and 21a passing through said insulating means 20 such a shown in the Figure. By rotating the disk a stepless regulated magnetic flux through the last turn is produced by the conductors 22a, 21 and 21a. This flux may be varied from zero to the flux through a full turn in the winding 22. The conductor 21 may either be insulated or in contact with the core 18b. Contacting of the second semi-conducting layer in the winding may be achieved by means of a sliding contact.

In Figures 6, 7 and 8 is illustrated a sliding contact device 60 which is particularly suitable for earthing ofthe second semiconducting layer. The contact is arranged at one end of the rotatable drum on which the regulating winding 22 is provided. The sliding contact includes an outer tube 62 and an inner tube 63, situated inside the outer tube. Both tubes are bent to form an substantially annual element located around the core 1. Between the two tubes one or several upset helicoidal, or canted coil, springs 63 are mounted. Both tubes as well as the helicoidal spring(s) are made of an electrically conducting material. The inner tube is in electrical contact with the outer tube by means of the spring. The outer tube 62 is provided with a axial slot 67 extending around its outer circumference and along the entire axial length of the tube. An outgoing conductor 68 is connected to the inner tube, for connection with earth. This conductor extends freely out through the slot. When the regulating drum rotates, the outer tube, connected to the drum, rotates also and both tubes are in electrical contact with each other by means of the helicoidal spring, functioning as a sliding contact. The outer tube is thereby connected to earth. As an alternative to the above, the inner tube may be the moving part while the outer tube is the stationary part provided with the outgoing conductor.

The outer tube 62 must be divided in order to achieve an electrical interruption in the circumference around the core. This may be solved by providing one or several interruptions 70 close to each other. When the sliding contact, i.e. the spring, passes these interruptions, an unwanted current may be produced in the spring, which may damage the spring.In order to prevent this, the device is provided with another type of contact 72 which commutates this current, for example a spring-loaded carbon contact.

Figure 4 illustrates a principle for earthing the second semiconducting layer of the winding. The regulating drum is provided with at least one feebly or moderately conducting ring 28 at its one end. This ring is highly resistant, at least at 100Ω and generally at 1000Ω, in order to prevent short circuit. The resistance of the ring can be evenly distributed along the ring or concentrated in areas having high resistance which are connected to well conducting material. Along the drum, i.e. in the axial direction and on the outside of the drum, yet under the winding itself, there are a plurality of elongated means 29, made of a conducting material, and arranged at regular intervals. These are connected to the ring 28 and thereby connected to each other. Earthing of the winding takes place through contact at the outer second layer of the winding having semiconducting properties. The storage drum 12 may also be provided with a corresponding arrangement 30.

Figure 5 shows a variant of the earthing of the outer second layer of the winding having semiconducting properties. The regulating drum is also provided here with a ring 38 which is connected to earth potential and located at the one end of this drum and extending around the circumference of the drum. Additional rings 40, made of a conducting material, are arranged at regular spaced apart intervals, around the semiconducting layer on the insulation of the conductor 36, so that the rings of one winding turn are in contact with the corresponding rings of the adjacent winding turns. In this way these rings form at least one continuous

electric connection 42 across the winding, and said connection is earthed through contact at the one end of the drum with the first ring 38 there located. Alternatively, the storage drum 12 may be earthed in a corresponding way or both drums may be earthed.

Finally, in Figure 9 is represented a cable which is particularly suitable to be used as a winding in the transformer/reactor according to the invention. The cable 50 includes at least one current carrying conductor 51 surrounded by a first semiconducting layer 52. Outside said first layer is provided a layer of solid insulation 53. Surrounding the insulation layer is then provided a second semiconducting layer 54. The current carrying conductor may include a number of strands 56, of which at least some are insulated from each other. The three layers of the cable, i.e. the two semiconducting layers and the insulation layer, are arranged to adhere to each other even when the cable is bent. The cable is consequently flexible and this property is maintained during the entire life of the cable. The illustrated cable also differs from conventional high voltage cables in that it does not have to include any outer layer for mechanic protection of the cable, nor does it have to include any metal shield which normally is provided on such a cable.

The above-mentioned embodiments and variations thereof are to be considered only by way of example of a non limited nature and the invention may thus be varied within the scope of the appended claims.

Patent claims

1. A method for regulating an induced voltage in a transformer, alternatively regulating the reactive power of a reactor, wherein a winding is achieved with an insulating electric conductor including at least one current carrying conductor, a first layer having semiconducting properties arranged to surround the conductor, a solid insulation layer arranged to surround said first layer, and a second layer having semiconducting properties arranged to surround the insulating layer, wherein a regulating winding is arranged around a magnetic flux carrier, and wherein the length of said regulating winding around the magnetic flux carrier is varied.

2. A method according to claim 1, **characterized** in that said regulating winding is arranged on a regulating winding means, said regulating means being rotatable around said magnetic flux carrier.

3. A method according to claim 1 or 2, **characterized** in that a variable part of the regulating winding is transferred to or from at least one storage means.

4. A method according to any one of the preceding claims, **characterized** in that the transformer/reactor includes a main winding with which the regulating winding may be connected..

5. A method according to claim 4, **characterized** in that starting from a zero position in which there is no winding on the regulating means, the induced voltage/reactive power of a transformer/reactor is increased in that the winding is wound onto the regulating winding means in the same direction as the direction of the main winding, and that the induced voltage/reactive power of a transformer/reactor respectively, is decreased in that the winding is wound onto the regulating winding means in the direction opposite to the direction of

the main winding, whereby the maximum variation of the number of winding turns is +-N, where N is the number of winding turns which are available on the regulating winding means.

6. A method according to any one of claims 4-5, **characterized** in that the existing length of winding on the regulating winding means is varied by stepless control, whereby the induced voltage and the reactive power respectively, are varied by stepless control.

7. A method according to any one claims 4-5, **characterized** in that the existing length of winding on the regulating winding means is varied by at least one winding turn at a time whereby the induced voltage and the reactive power respectively, are varied in steps corresponding to one winding turn.

8. A method according to any one of claims 3-7, **characterized** in that a storage means includes a rotatable storage drum, whereby the regulating winding means is rotated by means of a drive means so that the winding is transferred from the regulating winding means to the storage drum or vice versa.

9. A method according to any one of claims 2-8, **characterized** in that the regulating means includes a rotatable regulating winding drum.

10. An arrangement for regulating induced voltage in a transformer, alternatively regulating the reactive power of a reactor, wherein said transformer/reactor includes at least one magnetic flux carrier (1) and a winding (5; 26) achieved with an insulating electric conductor (50) including at least one current carrying conductor (51), a first layer (52) having semiconducting properties arranged to surround the conductor, a solid insulation layer (53) arranged to surround said first layer, and a second layer (54) having semiconducting properties arranged to surround the insulating layer,

wherein said arrangement further includes a regulating winding (3; 22) arranged around the magnetic flux carrier and a regulating means, by means of which the length of said regulating winding around the magnetic flux carrier is varied.

11. An arrangement according to claim 10, **characterized** in that said layers (52, 53, 54) are arranged to adhere to one another even when the insulated conductor is bent.

12. An arrangement according to claim 10 or 11, **characterized** in that the regulating winding is arranged on said regulating means and that said regulating means is rotatable around said magnetic flux carrier.

13. An arrangement according to any one of claims 10-12, **characterized** in that it includes at least one winding storage means (12) and means for transferring a variable part of the regulating winding (3; 22) to or from at least said storage means (12).

14. An arrangement according to any one of claims 10-13, **characterized** in that the regulating means includes a rotatable regulating winding drum (6).

15. An arrangement according to any one of claims 13-14, **characterized** in that the storage means includes a rotatable storage drum (12).

16. An arrangement according to any one of claims 13-158-10, **characterized** in that the storage means includes a second winding arranged around a magnetic flux carrier.

17. An arrangement according to any one of claims 13-16, **characterized** in that the regulating winding is arranged on a magnetic flux carrier leg belonging to one phase of a polyphase system and that the storage means includes a wind-

ing, arranged on a magnetic flux carrier leg belonging to another phase of the polyphase system.

18. An arrangement according to any one of the preceding claims, **characterized** in that the transformer/reactor includes a main winding (2) and that the regulating winding (3; 22) is provided with means for electric connection to the main winding.

19. An arrangement according to claim 18, **characterized** in that, starting from a zero position in which there is no winding on the regulating winding drum, the induced voltage/reactive power of a transformer/reactor respectively, is increased in that said means for transferring the winding (5) are adapted to winding up the winding onto the regulating winding drum (6) in the same direction as the direction of the main winding, and that the induced voltage reactive power of a transformer/reactor respectively, is reduced in that said means for transferring are adapted to winding up the winding (5) onto the regulating winding drum (6) in the direction opposite to the direction of the main winding, whereby the maximum variation of winding turns is +-N, where N is the number of winding turns which are available on the regulating winding drum.

20. An arrangement according to any one of claims 14-19, **characterized** in that said transferring means include drive means for the rotation of the regulating winding drum and drive means for the rotation of the storage drum.

21. An arrangement according to claim 20, **characterized** in that said drive means are in the form of at least one motor and a device for belt driving the respective drum.

22. An arrangement according to any one of claims 15-21, **characterized** in that the regulating winding drum (6) and

storage drum (12) respectively, are rotatable in two directions.

23. An arrangement according to any one of claims 18-22, **characterized** in that the means for electric connection to the main winding include a diverter switch (15) by means of which the length of the winding is varied by one winding turn at a time.

24. An arrangement according to any one of claims 18-22, **characterized** in that the magnetic flux carrier is a solid core and that said core is interrupted by an insulating means (20), whereby connection of the regulating winding (22) takes place through said insulating means and through the core, thereby obtaining a stepless variation of the length of the regulating winding.

25. An arrangement according to claim 24, **characterized** in that the last turn (22a, 21, 21a) of the regulating winding surrounds a magnetic flux which may vary between zero and the flow through a full turn of the winding (22).

26. An arrangement according to any one of claims 24-25, **characterized** in that said insulating means is composed of a rotatable disk (20) made of an insulating material.

27. An arrangement according to any one of the preceding claims, **characterized** in that the second layer (54) of the insulating electric conductor is connected to a predetermined potential.

28. An arrangement according to any one of claims 15-27, **characterized** in that at least one of the regulating drum (6) and the storage drum (12) respectively, is provided with means (60; 28,29; 38,40) for connecting said second layer (54), having semiconducting properties, to a predetermined potential.

29. An arrangement according to claim 27-28, **characterized** in that the predetermined potential is earth potential.

30. An arrangement according to any one of claims 28 or 29, **characterized** in that the means for connecting the second layer to a predetermined potential comprise a sliding contact, including an outer tube (62) and an inner tube (63), situated inside the outer tube, which tubes are bent to form a substantially annular element surrounding the core, adjacent to one end of the regulating means, in that one of said tubes is arranged to rotate with said regulating means and in that the other of said tubes is connected to earth, further including at least one helicoidal spring (63) mounted between said tubes, said tubes and said spring being made of an electrically conducting material, such that electrical contact is maintained between the inner tube and the outer tube by means of said spring when the regulating means rotates and the length of said regulating winding around the core is varied, whereby earthing is achieved.

31. An arrangement according to claim 30, **characterized** in that it further includes an outgoing conductor (68), that the outer tube is provided with an axial slot (67) extending along its outer circumference, and that said conductor (68) extends freely through said slot while one of the tubes rotates with the regulating means.

32. An arrangement according to any one of claims 28-29, **characterized** in that said means for connection to a predetermined potential include at least one partly conducting ring (28) which is connected to the predetermined potential and located at the one end of the drum as well as extending along its circumference, the ring being connected by means of a plurality of elongated means (29), made of a conducting material and arranged axially, on the outside of the drum, at regular intervals, whereby the winding (26) is provided on

the outside of said elongated means so that the second layer, having semiconducting properties, is in contact with said elongated means and that connection to the predetermined potential of the winding thereby takes place at regular intervals.

33. An arrangement according to any one of claims 28-29, **characterized** in that said means for connection to a predetermined potential include at least one partly conducting first ring (38) connected to a predetermined potential and located at the one end of the drum as well as extending along the circumference of the drum, a plurality of other rings (40), made of a conducting material, which are arranged around the insulating conductor (36) of the winding at regular intervals from each other, such that rings (40) of one winding turn are in contact with corresponding rings (40) of the adjacent winding turns, said rings thus forming at least one continuous electric connection across the winding, and that said connection is connected to said predetermined potential at the one end of the winding by means of contact with said first ring.

34. An arrangement according to any one of claims 32-33, **characterized** in that the partly conducting (first) ring has a high resistance.

35. An arrangement according to any one of claims 14-34, **characterized** in that the regulating winding drum consists of at least two drum parts (7, 8), which are joined together in the radial direction in order to form a drum.

36. A transformer/reactor, including a magnetic flux carrier and a regulating winding, **characterized** in that it includes an arrangement according to any one of claims 10-35.

37. A transformer/reactor according to claim 36, **characterized** in that it is a dry transformer/reactor.

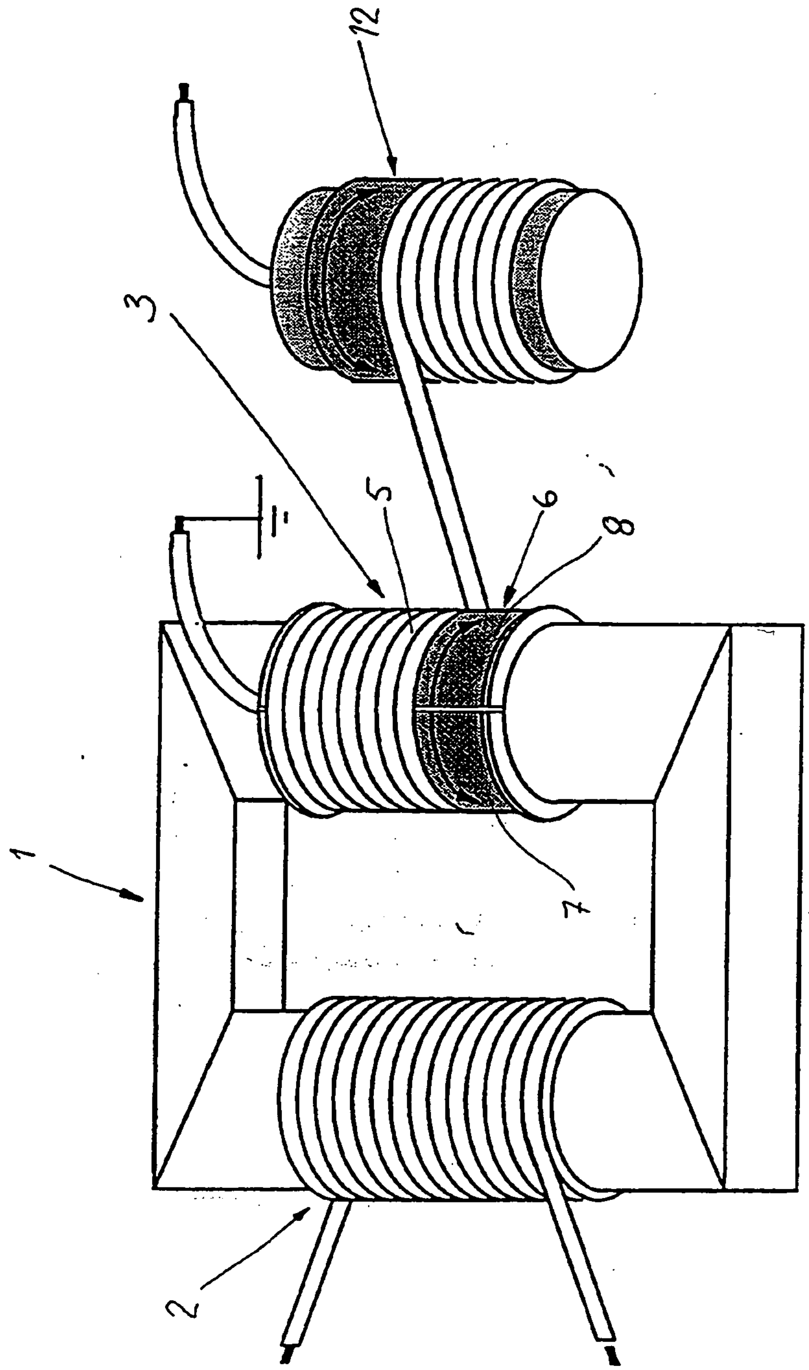

Fig. 1

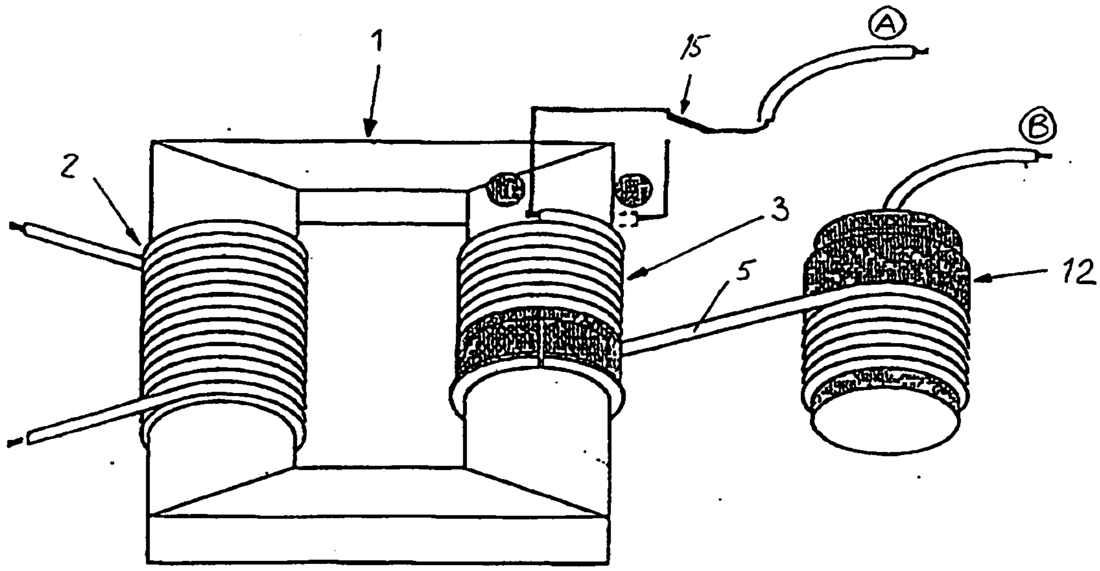

Fig. 2

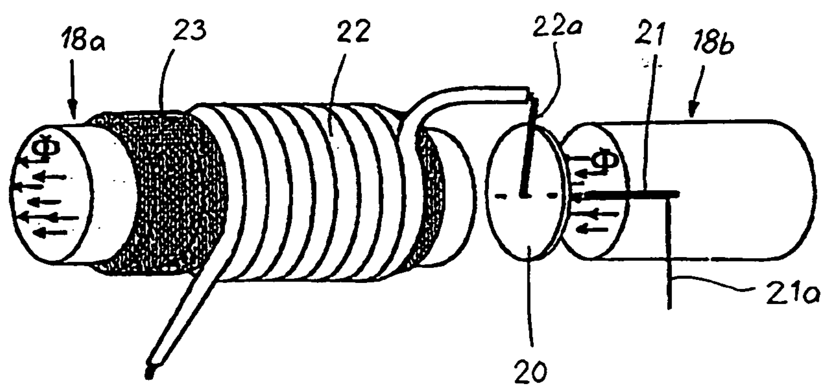

Fig. 3

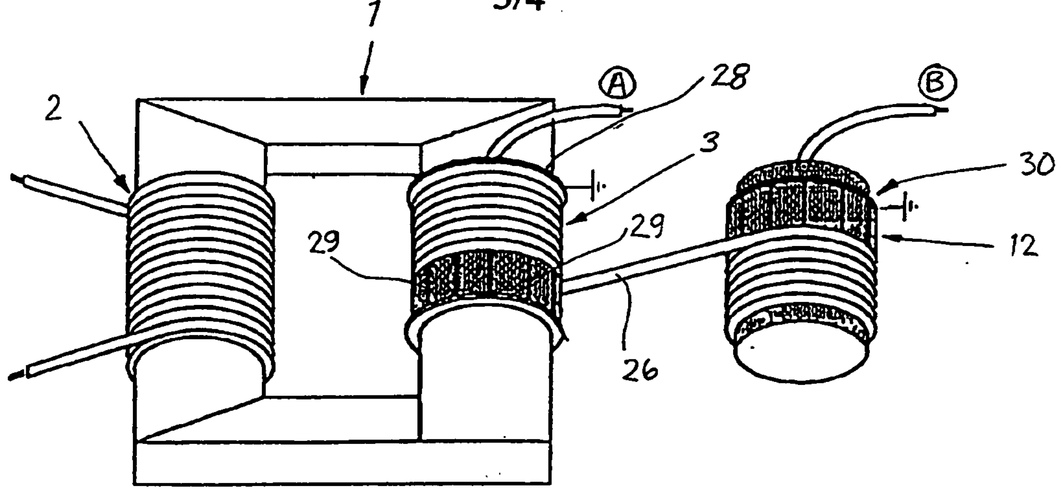

Fig. 4

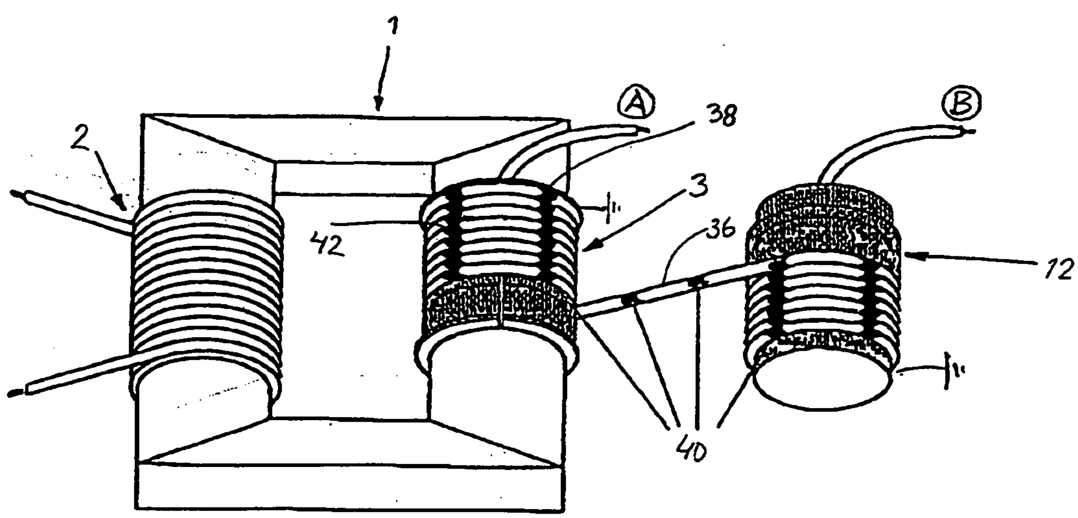

Fig. 5

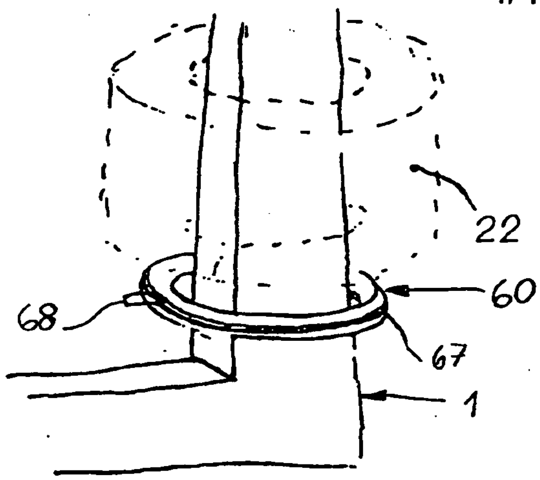

Fig. 6

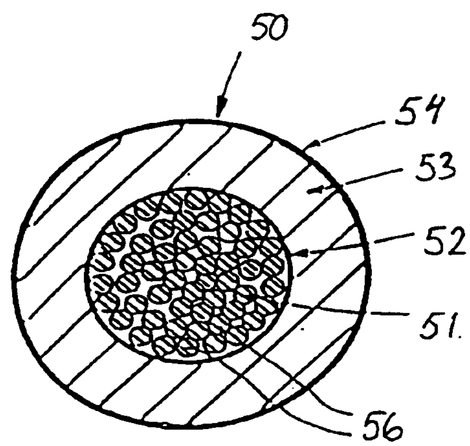

Fig. 9

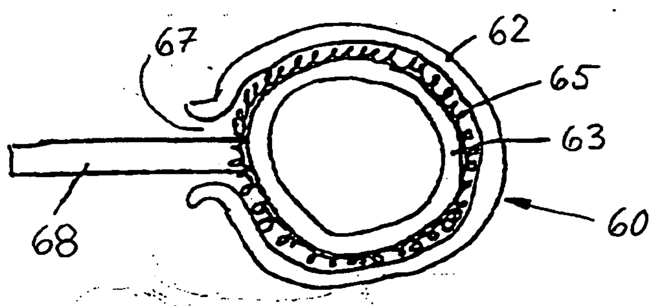

Fig. 7

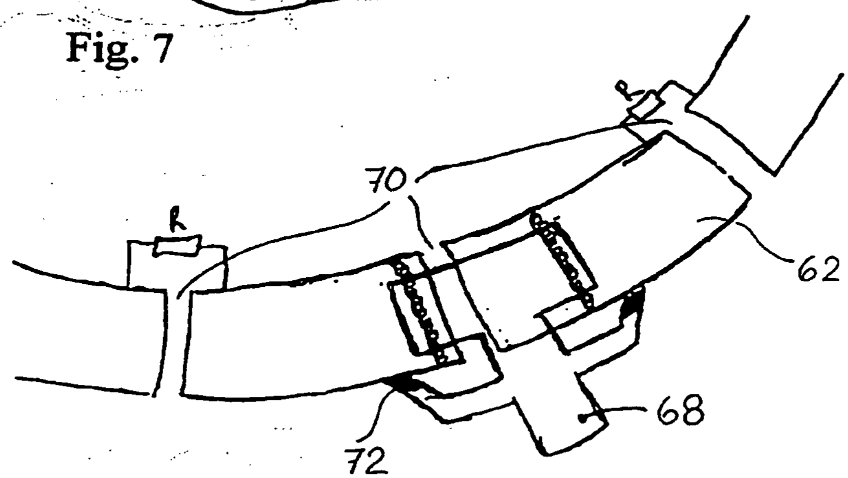

Fig. 8